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(पहला पुनरीक्षण)

Indian Standard

SEMICONDUCTOR OPTOELECTRONIC DEVICES FOR FIBRE OPTIC SYSTEM APPLICATIONS

PART 1 SPECIFICATION TEMPLATE FOR ESSENTIAL RATINGS AND CHARACTERISTICS

(First Revision)

ICS 33.180.01;31.260;31.080.01

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NEW DELHI 110002

August 2012 **Price Group 11**

Fibre Optics, Fibres, Cables and Devices Sectional Committee, LITD 11

NATIONAL FOREWORD

This Indian Standard (Part 1) (First Revision) which is identical with IEC 62007-1 : 2008 'Semiconductor optoelectronic devices for fibre optic system applications — Part 1: Specification template for essential ratings and characteristics' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Fibre Optics, Fibres, Cables and Devices Sectional Committee and approval of the Electronics and Information Technology Division Council.

This standard was originally published in 2002 which was identical with IEC 62007-1 : 1997 and has now been revised to align it with the latest version of IEC 62007-1 : 2008.

The text of IEC Standard has been approved as suitable for publication as an Indian Standard without deviations. Certain conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'.

b) Comma (,) has been used as a decimal marker while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to certain International Standards for which Indian Standards also exist. The corresponding Indian Standards which are to be substituted in their respective places are listed below along with their degree of equivalence for the editions indicated:

International Standard	*Corresponding Indian Standard*	*Degree of Equivalence*
IEC 60747-5-1 : 1997 Discrete semiconductor devices and integrated circuits — Part 5-1: Optoelectronic devices — General	IS 14901 (Part 5/Sec 1) : 2011 Semiconductor devices — Discrete devices and integrated circuits: Part 5 Optoelectronic devices, Section 1 General (*first revision*)	Identical
IEC 60825-2 : 1993 Safety of laser products — Part 2: Safety of optical fibre communication system (OFCS)	IS 14624 (Part 2) : 1998 Safety of laser products: Part 2 Safety of optical fibre communication system (OFCS)	do

The technical committee has reviewed the provision of the following International Standard referred in this adopted standard and has decided that it is acceptable for use in conjunction with this standard:

International Standard	*Title*
IEC 60825 (All parts except Part 2)	Safety of laser products

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

IS 15077 (Part 1) : 2012
IEC 62007-1 : 2008

Indian Standard

SEMICONDUCTOR OPTOELECTRONIC DEVICES FOR FIBRE OPTIC SYSTEM APPLICATIONS

PART 1 SPECIFICATION TEMPLATE FOR ESSENTIAL RATINGS AND CHARACTERISTICS

(First Revision)

1 Scope and object

This part of IEC 62007 is a specification template for essential ratings and characteristics of the following categories of semiconductor optoelectronic devices to be used in the field of fibre optic systems and subsystems:

- semiconductor photoemitters;
- semiconductor photoelectric detectors;
- monolithic or hybrid integrated optoelectronic devices and their modules.

The object of this performance specification template is to provide a frame for the preparation of detail specifications for the essential ratings and characteristics.

Detail specification writers may add specification parameters and/or groups of specification parameters for particular applications. However, detail specification writers may not remove specification parameters specified in this standard.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60825 (all parts), *Safety of laser products*

IEC 60747-5-1, *Discrete semiconductor devices and integrated circuits – Part 5-1: Optoelectronic devices – General*

3 Terms, definitions and abbreviations

For the purposes of this document, the following terms, definitions and abbreviations apply, as well as terms and definitions concerning *physical concepts*, *types of devices*, *general terms*, and *ratings and characteristics* given in IEC 60747-5-1.

3.1 Terms and definitions

3.1.1
PIN photodiode
photodiode with a large intrinsic region sandwiched between p- and n-doped semiconducting regions used for the detection of optical radiation

NOTE Adapted from IEV 731-06-29, specialized

3.1.2

avalanche photodiode

APD

photodiode operating with a bias voltage such that the primary photocurrent undergoes amplification by cumulative multiplication of charge carriers.

NOTE Adapted from IEV 731-06-30, specialized.

3.1.3

relative intensity noise

RIN

quotient of the radiant power mean square fluctuations $<\Delta\Phi_e^2>$ to the mean square radiant power $<\Phi_e>^2$, normalized to a frequency band of unit width

NOTE *RIN* is usually expressed in dB/Hz.

$$RIN = 10\log_{10}\left\{<\Delta\Phi_e^2>\Big/\left(<\Phi_e>^2\times\Delta f\right)\right\}$$

3.1.4

spectral shift

$\Delta\lambda_c$

deviation of the peak-emission wavelength at a particular case temperature or a particular forward current from its value at a specified reference case temperature or a specified reference forward current, respectively

NOTE The specific reference temperature is usually 25 °C.

3.1.5

input reflection coefficient

s_{11}

quotient of the high frequency reflected voltage to the high frequency incident voltage

3.1.6

tracking error

E_{tr}

deviation of the radiant power at a particular case temperature from its value at a specified reference case temperature

NOTE 1 The specific reference temperature is usually 25 °C.

NOTE 2 Specifications usually refer to the maximum deviation (absolute value) in two specified temperature ranges below and above the specified reference case temperature.

NOTE 3 The tracking error is usually expressed as a percentage of the radiant power at the reference case temperature.

3.1.7

(diode) responsivity R_D, R (of a photodiode)

quotient of the photocurrent I_p by the radiant power Φ_e at the optical port of the photodiode

NOTE 1 If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

NOTE 2 "Photodiode" means a complete device such as:

- chip itself;
- packaged component with window or pigtail.

3.1.8
excess noise factor
F_e
noise resulting from the spatial and timing fluctuations of the avalanche carrier multiplication: it is defined as the ratio of the noise power at a specified reverse bias to the amplified shot noise of the photocurrent at a reference reverse bias

NOTE The reference reverse voltage should be sufficiently low that no carrier multiplication takes place but sufficiently large that the device is fully depleted and has achieved its rated speed and responsivity.

3.2 Abbreviations

3.2.1
TEC
thermo-electric cooler

3.2.2
TIA
transimpedance amplifier

3.2.3
LED
light emitting diode

3.2.4
LD
laser diode

3.2.5
APD
avalanche photodiode

4 LEDs for fibre optic systems or subsystems

4.1 Type

Ambient-rated or case-rated LED with or without optical fibre pigtail for fibre optic systems or subsystems.

4.2 Semiconductor materials

GaAs, GaAlAs, InGaAs, InP, etc.

4.3 Details of outline and encapsulation

4.3.1 IEC and/or national reference number of outline drawing.

4.3.2 Method of encapsulation: glass/metal/plastic/other.

4.3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

4.3.4 Characteristics of the optical port: relative orientation to mechanical axis, relative position to mechanical axis, area, numerical aperture.

4.3.5 For devices with pigtail: information on the pigtail fibre, kind of protection, connector, length.

4.3.6 Information on the heat sink of the package.

4.4 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 1 – Limiting values for LEDs

Subclauses	Characteristics	Symbols	Requirements	
			Min.	Max.
4.4.1	Storage temperature	T_{stg}	x	x
4.4.2	Temperature			
either 4.4.2.1	Ambient temperature	T_{amb}	x	x
or 4.4.2.2	Case temperature	T_{case}	x	x
4.4.3	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		x
4.4.4	Reverse voltage	V_R		x
4.4.5	Continuous forward current Derating curve or derating factor	I_F		x
4.4.6	Repetitive peak forward current at specified pulse conditions (where appropriate) Derating curve or derating factor (where appropriate)	I_{FRM}		x
4.4.7	Power dissipation Derating curve or derating factor (where appropriate)	P_{tot}		x
4.4.8	For case-rated devices: Virtual junction temperature (where appropriate)	T_{vj}		x
4.4.9	For devices with pigtail: Bend radius of pigtail (at specified distance from the case)	r	x	
4.4.10	Shock			x
4.4.11	Vibration			x
4.4.12	Tensile force on devices with pigtail:			
4.4.12.1	Untight structure:			
	– Tensile force on fibre along its axis	F		x
	– Tensile force on cladding along its axis	F		x
4.4.12.2	Tight structure:			
	– Tensile force on pigtail along its axis	F		x

4.5 Electrical and optical characteristics

Table 2 – Electrical and optical characteristics for LEDs

Subclauses	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C unless otherwise stated	Symbols	Requirements	
				Min.	Max.
4.5.1	Forward voltage	I_F or Φ_e specified	V_F		x
4.5.2	Reverse current	V_R specified	I_R		x
4.5.3	Differential resistance	I_F or Φ_e specified	$\mathrm{r_d}$		x
4.5.4	Total capacitance	V_R, f specified	$\mathrm{C_{tot}}$		x
4.5.5	Noise parameter				
either 4.5.5.1	Relative intensity noise (where appropriate)	I_F or Φ_e, f_o, Δf_N specified	*RIN*		x
or 4.5.5.2	Carrier-to-noise ratio (where appropriate)	I_F or Φ_e, f_c, Δf_N, f_m, m specified	*C/N*		x
4.5.6	Output parameter				
either 4.5.6.1	Radiant output power	I_F specified (d.c. or pulse, or both)	Φ_e	x	x [a]
or 4.5.6.2	Forward current	Φ_e specified	I_F	x [a]	x
4.5.7	For devices without pigtail: Half-intensity angle (where appropriate)	I_F or Φ_e, angle ϕ specified	$\theta_{1/2}$		x
4.5.8	For devices without pigtail: Misalignment angle (where appropriate)	I_F or Φ_e, angle ϕ specified	$\Delta\theta$		x
4.5.9	Spectral radiation bandwidth	I_F or Φ_e specified	$\Delta\lambda$		x
4.5.10	Bandwidth				
either 4.5.10.1	Switching times: – rise time – fall time – delay times (where appropriate) – peak emission wavelengths	DC current, input pulse current pulse width and duty cycle specified	t_r t_f $t_{d(on)}$/ $t_{d(off)}$		x x x x
or 4.5.10.2	Cut-off frequency	I_F or Φ_e specified	f_c	x	

[a] Where appropriate.

4.6 Supplementary information

4.6.1 Typical curve or coefficient

Provide the curve or coefficient in 4.6.1.1 or 4.6.1.2.

4.6.1.1 Typical curve or coefficient of radiant power versus temperature and typical curve of radiant output power versus forward current (d.c. or pulse, as specified).

4.6.1.2 Typical curve or coefficient of radiant intensity versus temperature and typical curve of radiant intensity versus forward current (d.c. or pulse, as specified).

4.6.2 Typical curve or coefficient of change in peak emission wavelength versus temperature.

4.6.3 Typical radiation diagram.

4.6.4 Thermal resistance, ambient-rated or case-rated.

5 Laser module with pigtails

5.1 Type

The laser module consists of the following basic parts:

- laser diode
- pigtail
- photodiodes
- thermal sensor } where appropriate
- TEC element

5.2 Semiconductor

5.2.1 Materials

The laser module consists of the following materials:

– laser diode	e.g. GaAs, GaAlAs, InGaAsP, InP
– photodiode	e.g. Ge, Si, GaInAs
– thermal sensor }	where appropriate
– TEC element	

5.2.2 Structure

Laser diode, e.g.: gain guided, index guided, distributed feedback, etc.

5.3 Details of outline and encapsulation

5.3.1 IEC and/or national reference number of the outline drawing.

5.3.2 Method of encapsulation: glass/metal/plastic/other.

5.3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

5.3.4 Information on the pigtail fibre, e.g.: type of fibre, kind of protection, connector, length.

5.3.5 Information on the heatsinking of the package.

5.4 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

General conditions

5.4.1 Minimum and maximum storage temperatures (T_{stg}).

5.4.2 Minimum and maximum operating case temperatures (T_{case}).

5.4.3 Minimum and maximum operating submount temperature (T_{sub}).

5.4.4 Maximum soldering temperature (soldering time and minimum distance to case) (T_{sld}).

5.4.5 Minimum bend radius of pigtail (at specified distance from the case) (r).

5.4.6 Shock (maximum acceleration and pulse duration).

5.4.7 Vibration (maximum acceleration and frequency range).

5.4.8 Tensile force along cable axis.

5.4.8.1 Untight structure:

- Maximum tensile force on fibre (F).
- Maximum tensile force on cable (F).

5.4.8.2 Tight structure:

- Maximum tensile force on cable (F).

Laser diode

For laser module without TEC, derating curve or derating factor must be given for one of following parameters, 5.4.10 to 5.4.13. For laser module with TEC, T_{sub} equals to 25 °C.

5.4.9 Maximum reverse voltage (V_{R}).

5.4.10 Maximum continuous forward current (I_{F}).

5.4.11 Maximum continuous radiant power (ϕ_{e}).

5.4.12 Maximum pulsed forward current at stated frequency and pulse duration (I_{FP}).

5.4.13 Maximum pulsed radiant power at stated frequency and pulse duration (ϕ_{ep}).

Photodiode

5.4.14 Maximum reverse voltage (V_{R}).

5.4.15 Maximum forward current (I_{F}).

Thermal sensor (where appropriate)

5.4.16 Maximum ratings

5.4.16.1 Maximum power dissipation (P).

or

5.4.16.2 Maximum voltage supply (V).

Thermoelectric cooler (where appropriate)

5.4.17 Maximum cooler current under cooling and heating (I_{PE}).

5.5 Electric and optical characteristics

Table 3 – Electric and optical characteristics for laser modules with pigtails

Subclauses	**Characteristics**	**Conditions at T_{sub} = 25 °C** **for laser with TEC,** **T_{amb} or T_{case} = 25 °C for laser module without TEC** **unless otherwise stated**	**Symbols**	**Requirements**	
A. Laser diode					
5.5.1	Forward voltage	I_F or Φ_e specified	V_F		Max.
5.5.2	Threshold current		$I_{(TH)}$	Min.	Max.
5.5.3	Radiant power at threshold	$I_F = I_{TH}$	$\phi_{e(TH)}$		Max.
5.5.4	Forward current above threshold (for laser module without TEC)	Φ_e specified $T = T_{\text{case}}$ max. or T_{amb} max.	ΔI_F		Max.
5.5.5	Differential efficacy (for laser module without TEC)	Φ_e or ΔI_F specified $T = T_{\text{case}}$ max. or T_{amb} max.	η_d	Min.	Max.
5.5.6	Spectral characteristics				
5.5.6.1	Spectral characteristics				
5.5.6.1.1	Peak emission wavelength	Φ_e or ΔI_F specified CW-operation	λ_p [a]	Min.	Max.
5.5.6.1.2	Spectral radiation bandwidth FWHM	Φ_e or ΔI_F specified CW-operation	λ_p [a]		Max.
or 5.5.6.1.3	Mode spacing and number of longitudinal modes	Φ_e or ΔI_F specified CW-operation	η_m		Max.
5.5.6.1.4	Peak emission wavelength under modulation	Φ_e or ΔI_F specified modulation condition specified	λ_p [b]	Min.	Max.
5.5.6.1.5	Spectral radiation bandwidth under modulation	Φ_e or ΔI_F specified modulation condition specified	λ_p [b]		Max.
5.5.6.2	Additional spectral characteristics				
and/or 5.5.6.2.1	Centroidal wavelength	Φ_e or ΔI_F specified CW-operation	λ_{avg}[a]	Min.	Max.
5.5.6.2.2	Spectral radiation r.m.s. bandwidth	Φ_e or ΔI_F specified	$\Delta\lambda_{rms}$ [a]		Max.
or 5.5.6.2.3	Mode spacing and number of longitudinal modes	Φ_e or ΔI_F specified	η_m		Max.
5.5.6.2.4	Central wavelength under modulation	Φ_e or ΔI_F specified modulation condition specified	λ [b]	Min.	Max.
5.5.6.2.5	Spectral radiation r.m.s. bandwidth under modulation	Φ_e or ΔI_F specified modulation condition specified	$\Delta\lambda_{rms}$ [b]		Max.
5.5.7	Single spectral mode laser module under specified direct modulation				
5.5.7.1	Spectral mode width	Φ_e or ΔI_F specified modulation condition specified	$\Delta\lambda_L$		Max.
5.5.7.2	Side-mode suppression ratio	Φ_e or ΔI_F specified modulation condition specified	$SMSR$	Min.	
5.5.8	Spectral shift				

Subclauses	**Characteristics**	**Conditions at T_{sub} = 25 °C for laser with TEC, T_{amb} or T_{case} = 25 °C for laser module without TEC unless otherwise stated**	**Symbols**	**Requirements**	
5.5.8.1	Spectral shift for module with TEC	ΔI_{F1}, ΔI_{F2}, ϕ_{e1}, ϕ_{e2}	$\Delta\lambda_c$		Max.
5.5.8.2	Spectral shift for laser module without TEC	T_{amb} [a] or T_{case} [a], T_{amb} [b] or T_{case} [b]	$\Delta\lambda_c$		Max.
5.5.9	Transient parameters				
5.5.9.1	Rise time, fall time	Bias current ΔI_F or ϕ_e	t_r, t_f		Max.
and/or		input pulse current,			
5.5.9.2	Turn-on time, turn-off time	width and duty cycle specified	t_{on}, t_{off}		Max.
5.5.10	Cut-off frequency	Φ_e or ΔI_F specified	f_c	Min.	Max.
5.5.11	Carrier-to-noise ratio	ΔI_F or Φ_e, Δf, f_m, m and f_0 specified	C/N	Min.	
B. Monitor photodiode					
5.5.12	Dark current	$\Phi_e = 0$ V_R specified	$I_{r(0)}$		Max.
5.5.13	Reverse current under optical radiation	Φ_e or ΔI_F specified V_R specified	$I_{R(e)}$	Min.	Max.
5.5.14	Diode capacitance or rise/fall time				
either 5.5.14.1	Diode capacitance	V_R and f specified	C_{tot}		Max.
or 5.5.14.2	Rise time, fall time	Φ_e or ΔI_F specified V_R specified	t_r, t_t		Max.
5.5.15	Tracking error				
5.5.15.1	Tracking error	Φ_e or ΔI_F and V_R specified, Temperature range: 25 °C to T_{case} min. or T_{amb} min.	E_{R1}		Max.
and/or 5.5.15.2	Tracking error	Φ_e or ΔI_F and V_R specified, Temperature range: 25 °C to T_{case} min. or T_{amb} min.	E_{R2}		Max.
C. Thermistor (where appropriate)					
5.5.16	Resistance	Thermistor current I_{tc} specified	R	Min.	Max.
5.5.17	Slope of resistance	Thermistor current I_{tc} specified. Temperature range: T_{sub} [a], T_{sub} [b]	$\Delta R/R$	Min.	Max.
D. TEC current (where appropriate)					
5.5.18	TEC current	Φ_e or ΔI_F specified, Temperature range: T_{case} min. or T_{case} max.	I_{PE}		Max.
5.5.19	TEC voltage	Φ_e or ΔI_F specified, Temperature range: T_{case} or T_{amb} min. and max.	V_{PE}		Max.

[a] CW-operation.

[b] In modulation.

5.6 Supplementary information

5.6.1 DC forward current of the laser diode corresponding to ϕ_{eoo}.

NOTE ϕ_{eoo}: radiant power value of the laser chip on submount, representative of the performance and reliability of devices manufactured using the same technology and submitted to the same quality assurance procedures.

5.6.2 Response time of the thermistor temperature to the change of cooler current (where appropriate).

5.6.3 Thermal resistance between laser diode junction and case (without cooler): R_{thj-c}.

5.6.4 s_{11} parameter.

5.7 Hazards

See IEC 60825.

6 PIN photodiodes for fibre optic systems or subsystems

6.1 Type

Ambient-rated or case-rated PIN photodiodes with or without optical fibre pigtail for fibre optic systems or subsystems.

6.2 Semiconductor materials

Si, Ge, InGaAs, etc.

6.3 Details of outline and encapsulation

6.3.1 IEC and/or national reference number of outline drawing.

6.3.2 Method of encapsulation: glass/metal/plastic/other.

6.3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

6.3.4 Characteristics of the optical port: relative orientation to mechanical axis, relative position to mechanical axis, area, numerical aperture.

6.3.5 For devices with pigtail: information on the pigtail fibre, type of fibre, kind of protection, connector, length.

6.3.6 Information on the heat sink of the package.

6.4 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 4 – Limiting values for PIN photodiodes

Subclauses	Characteristics	Symbols	Requirements	
			Min.	Max.
6.4.1	Storage temperature	T_{stg}	x	x
6.4.2	Temperature			
either 6.4.2.1	Ambient temperature	T_{amb}	x	x
or 6.4.2.2	Case temperature	T_{case}	x	x
6.4.3	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		x
6.4.4	Reverse voltage	V_R		x
6.4.5	Power dissipation	P_{tot}		x
6.4.6	Radiant power on the sensitive area	Φ_e		x
6.4.7	For devices with pigtail: Bend radius of pigtail (at specified distance from the case)	r	x	
6.4.8	Shock			x
6.4.9	Vibration			x
6.4.10	Tensile force on devices with pigtail:			
6.4.10.1	Untight structure:			
	– Tensile force on fibre along its axis	F		x
	– Tensile force on cladding along its axis	F		x
6.4.10.2	Tight structure:			
	– Tensile force on pigtail along its axis	F		x

6.5 Electrical and optical characteristics

Table 5 – Electrical and optical characteristics for PIN photodiodes

Subclauses	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C unless otherwise stated	Symbols	Requirements	
				Min.	Max.
6.5.1	Dark current				
6.5.1.1	Dark current	V_{R} specified, $\Phi_{\text{e}} = 0$	$I_{\text{R(D)}}$ [a]		x
6.5.1.2	Dark current at high temperature	V_{R} specified, $\Phi_{\text{e}} = 0$ T_{amb} or T_{case} specified	$I_{\text{R(D)}}$ [b]		x
6.5.2	Total capacitance	V_{R}, f specified, $\Phi_{\text{e}} = 0$	C_{tot}		x
6.5.3	Noise current	V_{R}, $I_{\text{R(e)}}$, f_0, Δf_{N}, R_{L}, λ_{p}, $\Delta\lambda$ specified	I_{n}		x
6.5.4	For devices without pigtail:				
6.5.4.1	Sensitivity along the specified mechanical axis	V_{R}, λ_{p}, $\Delta\lambda$, Φ_{e} specified	S_{FD}, S	x	x [a]
6.5.4.2	Spatial uniformity of sensitivity (where appropriate)	V_{R}, λ_{p}, $\Delta\lambda$ or Φ_{e} specified	ΔS		x
6.5.5	For devices with pigtail: Sensitivity	V_{R}, λ_{p}, $\Delta\lambda$, Φ_{e} specified	S_{FD}, S	x	x [a]
6.5.6	Bandwidth				
either 6.5.6.1	Switching time: – Rise time – Fall time – Delay times (where appropriate) – Storage time	V_{R}, λ_{p}, $\Delta\lambda$, pulse base Φ_{e1}, pulse top Φ_{e2}, R_{L} specified	t_{r} t_{t} $t_{\text{d(on)}}$/ $t_{\text{d(off)}}$ t_{s}		x x x x
or 6.5.6.2	Cut-off frequency	V_{R}, λ_{p}, $\Delta\lambda$, Φ_{e}, R_{L} specified	f_{c}	x	

NOTE The specified voltage V_{R} is the same for all the characteristics, unless otherwise stated

[a] Where appropriate.

[b] Term and/or letter symbol under consideration.

6.6 Supplementary information

6.6.1 Typical curve of dark current versus voltage, at different temperatures.

6.6.2 Typical curve of total capacitance versus reverse voltage.

6.6.3 Relative sensitivity versus wavelength.

6.6.4 Relative sensitivity versus temperature.

6.6.5 Derating curve or derating factor of maximum dissipation.

7 Avalanche photodiodes (APDs) with or without pigtails

7.1 Type

Ambient-rated or case-rated avalanche photodiode for fibre optic systems or subsystems.

7.2 Semiconductor

7.2.1 Materials

Si, Ge, InGaAs, etc.

7.2.2 Structure

7.3 Details of outline and encapsulation

7.3.1 IEC and/or national reference number of outline drawing.

7.3.2 Method of encapsulation: glass/metal/plastic/other.

7.3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

7.3.4 Characteristics of the optical port: relative orientation to the mechanical axes, relative position to mechanical axes, area, numerical aperture.

7.3.5 Information on the pigtail fibre (where appropriate): type of fibre, kind of protection, connector, length.

7.4 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

7.4.1 Minimum bend radius of the pigtail, where appropriate.

7.4.2 Minimum and maximum storage temperature (T_{stg}).

7.4.3 Minimum and maximum operating ambient or case temperatures (T_{amb} or T_{case}).

7.4.4 Maximum soldering temperature (T_{sld}) (soldering time and minimum distance to case to be specified).

7.4.5 Maximum power dissipation at ambient or case temperature of 25 °C (P_{tot}) and derating curve or derating factor.

7.4.6 Maximum pull force for pigtail (fibre or cable), where appropriate, in the direction of the axis of the input pigtail (fibre or cable).

7.4.7 Maximum reverse current (I_{R}).

7.4.8 Maximum forward current (I_{F}).

7.5 Electrical and optical characteristics

V_{R} shall be the same for all characteristics; it shall be equal to 0,9 of the individually measured value of $V_{\mathrm{(BR)}}$, unless otherwise specified.

Table 6 – Electrical and optical characteristics for avalanche photodiodes (APDs) with or without pigtails

Subclauses	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C unless otherwise stated	Symbols	Requirements	
7.5.1	Breakdown voltage	E_e or $\phi_e = 0$, I_R specified	$V_{(BR)}$	Min.	Max.
7.5.2	Reverse dark current				
7.5.2.1	Reverse dark current (NOTE 1)	E_e or $\phi_e = 0$, V_R specified	I_R [a]		Max.
7.5.2.2	Reverse dark current (NOTE 2)	E_e or $\phi_e = 0$, V_R specified $T = T_{amb}$ max. or T_{case} max.	I_R [b]		Max.
7.5.3	Sensitivity				
7.5.3.1	Sensitivity (NOTE 1)	V_{R1} (NOTE 2), ϕ_e, λ_{pp}, $\Delta\lambda$ specified	S [a]	Min.	Max. (NOTE 1)
7.5.3.2	Sensitivity (NOTE 2)	V_R, ϕ_e, λ_p, $\Delta\lambda$ specified	S [b]	Min.	Max. (NOTE 2)
7.5.4	Multiplication factor	V_{R1} (NOTE 2), λ_p, $\Delta\lambda$, ϕ_e, specified	M	Min.	
7.5.5	Total capacitance	E_e or $\phi_e = 0$; V_R, f specified	C_{tot}		Max.
7.5.6	Small signal parameters				
7.5.6.1	Turn-on time and turn-off time	V_R, $\Delta\lambda$, R_L, ϕ_{e1}: peak radiant power ϕ_{e2}: offset radiant power	t_{on} t_{off}		Max. Max.
7.5.6.2	Small signal cut-off frequency	V_R, λ_p, $\Delta\lambda$, ϕ_e and R_L specified	f_c	Min.	
7.5.7	Excess noise factor	V_{R1} (NOTE 2), V_R, I_{PO}, λ_p, $\Delta\lambda$, M, f_0, Δf_N, specified	F_e		Max.
7.5.8	Noise current (where appropriate)	V_R, λ_p, $\Delta\lambda$, f, Δf_N specified	I_n		Max.

NOTE 1 Where appropriate.

NOTE 2 V_{R1} should be a small value at which negligible carrier multiplication takes place, or the voltage at which the device is fully depleted and has achieved its rated speed.

[a] Where appropriate.

[b] Term and/or letter symbol under consideration.

7.6 Supplementary information

7.6.1 Curve of breakdown voltage versus temperature.

7.6.2 Curve of sensitivity versus wavelength.

7.6.3 Curve of capacitance versus reverse voltage.

7.6.4 Curve of multiplication factor versus reverse voltage at different temperatures.

7.6.5 Curve of reverse dark current versus reverse voltage at different temperatures.

7.6.6 Location of sensitive area by reference to the package (without pigtail).

7.6.7 Curve of excess noise factor versus reverse voltage (where appropriate).

7.6.8 Curve of noise current versus reverse voltage (where appropriate).

8 PIN-TIA modules for fibre optic systems or subsystems

8.1 Type

Ambient-rated or case-rated PIN-TIA modules for fibre optic systems or subsystems.

The PIN-TIA module consists of the following basic parts:

- PIN photodiode;
- TIA circuits;
- fibre pigtail, pigtail connectors, receptacles (connecterized package).

8.2 Semiconductor materials

The PIN-TIA module consists of the following semiconductor materials :

- PIN photodiode: Si, Ge, InGaAs, etc ;
- TIA circuit: GaAs, Si, etc.

8.3 Structure

The structure of the PIN-TIA module is

- PIN photodiode: Mesa, planar, etc ;
- TIA circuit: CMOS, Bi-CMOS, HBT, Bi-polar etc ;
- information on the fibre coupling: taper type, lens coupling, etc ;
- information on the circuit: high impedance, transimpedance, bandwidth, etc ;
- information on the package: pigtail, receptacle (connecterized package), etc.

8.4 Details of outline and encapsulation

- IEC and/or national reference number of outline drawing.
- Method of encapsulation: glass/metal/plastic/other.
- Terminal identification and indication of any electrical connection between a terminal and the case.
- Characteristics of the optical port: orientation relative to mechanical axis, position relative to mechanical axis, area, numerical aperture.
- Information on the pigtail fibre: type of fibre, kind of protection, connector, length.
- Information on the connector/receptacle.

8.5 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 7 – Limiting values for PIN-TIA modules

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
8.5.1	Storage temperature	T_{stg}	x	x	°C
8.5.2	Operating temperature				
either 8.5.2.1	Operating ambient temperature	T_{amb}	x	x	°C
or 8.5.2.2	Operating case temperature	T_{case}	x	x	°C
8.5.3	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		x	°C
8.5.4	Supply voltages at specified terminals	V_{supp}	x	x	V
8.5.5	Radiant power at optical port	Φ_{e}		x	mW(W)
8.5.6	Bend radius of pigtail (at specified distance from the case)	r	x		mm(cm)
8.5.7	Shock			x	m/s^2, s
8.5.8	Vibration			x	m/s^2, Hz
8.5.9	Tensile force along cable axis:				
8.5.9.1	Untight structure				
	– Tensile force on fibre	F		x	N
	– Tensile force on cable	F		x	N
8.5.9.2	Tight structure				
	– Tensile force on cable	F		x	N

8.6 Operating conditions at T_{amb} = 25 °C, unless otherwise stated

Table 8 – Operating conditions for PIN-TIA modules

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
8.6.1	Supply voltages specified by terminal number	V_{supp}	x	x	V
8.6.2	Supply current (at T_{amb} max.) specified by terminal number	I_{supp}		x	mA
8.6.3	Load resistance	R_{L}	x		Ω

8.7 Electrical and optical characteristics

Table 9 – Electrical and optical characteristics for PIN-TIA modules

Subclauses	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Symbols	Requirements		Units
				Min.	Max.	
8.7.1	Minimum detectable power	a) λ_p, $\Delta\lambda$, f_{mB}, B and C/N specified or b) λ_p, $\Delta\lambda$, bit rate, signal pattern and bit error rate specified	Φ_{eD}	x		dBm
8.7.2	Output noise power density	R_L, f_m, B, Φ_e specified λ_p, $\Delta\lambda$ specified	P_{n0}, λ		x	W/Hz
8.7.3	Frequency					
8.7.3.1	Low frequency output noise power density	R_L, f_m, B, λ_p and $\Delta\lambda$ specified, Φ_e = 0	P_{n0}, λ		x	W/Hz
and			L_F			
8.7.3.2	Corner frequency	R_L, f_m, B, λ_p and $\Delta\lambda$ specified, Φ_e = 0	f_{cor}		x	Hz
8.7.4	Responsivity					
8.7.4.1	Responsivity (for module)	λ_p, $\Delta\lambda$, Φ_e, R_L specified	R_D	x		V/W
and						
8.7.4.2	Responsivity (for PIN photodiode only) (where appropriate)	V_R, λ_p, $\Delta\lambda$, Φ_e specified	R_D	x		A/W
8.7.5	Frequency response flatness	λ_p, $\Delta\lambda$, Φ_e, R_L specified f_1 and f_2 specified	$\Delta R_D/R_D$		x	
8.7.6	Bandwidth					
either 8.7.6.1	Switching time:					
	– Rise time	λ_p, $\Delta\lambda$, Φ_{e1}, Φ_{e2}, R_L specified	t_r		x	ns
	– Fall time		t_f		x	ns
or 8.7.6.2	Cut-off frequency	λ_p, $\Delta\lambda$, Φ_e, R_L specified	f_c	x		MHz (GHz)
8.7.7	Offset voltage (where appropriate)	λ_p, $\Delta\lambda$, Φ_e, R_L specified	V_{off}	x	x	V
8.7.8	Dark current (PIN photodiode only) (where appropriate)	V_R specified, Φ_e = 0	I_R		x	nA

8.8 Supplementary information

- Relative responsivity versus wavelength
- Typical thermal variation of the offset voltage
- Information on the equalization

9 Laser diode modules for pumping an optical fibre amplifier

9.1 Type

The laser module consists of the following basic parts:

- laser diode;
- fibre pigtail (where appropriate);

- lenses (where appropriate);
- photodiode (where appropriate);
- thermal sensor (where appropriate);
- TEC element (where appropriate);
- isolator (where appropriate).

9.2 Semiconductor materials

The laser diode module for pumping an optical fibre amplifier consists of the following semiconductor materials:

- laser diode: GaAs, GaAlAs, InGaAs, InGaAsP, InP, etc.
- photodiode: Ge, Si, InGaAs, etc.
- thermal sensor: } where appropriate
- TEC element: }

9.3 Structure

Laser diode: gain guided, index guided, distributed feedback, ridge waveguide, BH, etc.

9.4 Details of outline and encapsulation

- IEC and/or national reference number of the outline drawing.
- Method of encapsulation: glass/metal/plastic/other.
- Terminal identification and indication of any electrical connection between a terminal and the case.
- Characteristics of the optical port: orientation relative to mechanical axis, position relative to mechanical axis, area, numerical aperture.
- Information on the pigtail fibre: type of fibre, kind of protection, connector, and length.
- Information on the heat sinking of the package.

9.5 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 10 – Limiting values for laser diode modules for pumping an optical fibre amplifier

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
	A. General conditions				
9.5.1	Storage temperature	T_{stg}	x	x	°C
9.5.2	Operating case temperature	T_{case}	x	x	°C
9.5.3	Operating submount temperature (where appropriate)	T_{sub}	x	x	°C
9.5.4	Soldering temperature at maximum soldering time and at specified minimum distance to case	T_{sld}		x	°C
9.5.5	Bend radius of pigtail (at specified distance from the case)	r	x		mm (cm)
9.5.6	Shock			x	m/s^2, s
9.5.7	Vibration			x	m/s^2, Hz
9.5.8	Tensile force along cable axis				
9.5.8.1	Untight structure – Tensile force on fibre – Tensile force on cable	 F F		 x x	 N N
9.5.8.2	Tight structure – Tensile force on cable	 F		 x	 N
	B. Laser diode [a]				
9.5.9	Reverse voltage	V_{R}		x	V
9.5.10	Continuous forward current	I_{F}		x	mA
9.5.11	Continuous radiant power	Φ_{e}		x	mW
	C. Photodiode (where appropriate)				
9.5.12	Reverse voltage	V_{R}		x	V
9.5.13	Forward current	I_{F}		x	mA
	D. Thermal sensor (where appropriate)				
9.5.14	Thermal sensor				
either 9.5.14.1	Dissipation	P		x	W
or 9.5.14.2	Supply voltage	V_{supp}		x	V
	E. Thermoelectric cooler (where appropriate)				
9.5.15	TEC current under cooling and heating	I_{p}		x	A

[a] For laser module without TEC, the derating curve or derating factor shall be given for one of the parameters of 9.5.10 to 9.5.13. For laser module with TEC, T_{sub} = 25 °C.

9.6 Electrical and optical characteristics

Table 11 – Electrical and optical characteristics for laser diode modules for pumping an optical fibre amplifier

Subclauses	Characteristics	Conditions at T_{sub} = 25 °C for laser modules with TEC, T_{amb} or T_{case} = 25 °C for laser module without TEC, unless otherwise specified	Symbols	Requirements		Units
				Min.	Max.	
	A. Laser diode					
9.6.1	Forward voltage	Φ_e or I_F specified	V_F		x	V
9.6.2	Forward current					
9.6.2.1	Forward current	Φ_e specified	$I_{F\,a}$		x	mA
9.6.2.2	Forward current at high temperature	Φ_e specified $T_{case} = T_{case}$, max.	$I_{F\,b}$		x	mA
9.6.3	Threshold current		$I_{(TH)}$	x	x	mA
9.6.4	Differential efficiency	Φ_e or ΔI_F specified $(\Delta I_F = I_F - I_{(TH)})$	η_d	x	x	m
9.6.5	Spectral characteristics					
9.6.5.1	Peak emission wavelength	Φ_e or ΔI_F specified, CW condition	λ_p	x	x	nm
either 9.6.5.2	Spectral radiation r.m.s. bandwidth	Φ_e or ΔI_F specified, CW condition	$\Delta\lambda_{rms}$		x	nm
or 9.6.5.3	Spectral radiation bandwidth (FWHM)	Φ_e or ΔI_F specified, CW condition	$\Delta\lambda$		x	nm
9.6.5.4	Spectral shift with current or radiant power	ΔI_F [a], ΔI_F [b] or Φ_e [a], Φ_e [b], specified	$\Delta\lambda_C$ or $\Delta\lambda_p$		x x	nm/mA nm/mW
9.6.5.5	Spectral shift with temperature (for laser module with TEC)	T_{case} [a], T_{case} [b] specified Φ_e or ΔI_F specified	$\Delta\lambda_T$		x	nm/°C
9.6.5.6	Spectral shift with temperature (for laser module with TEC)	T_{amb} [a], T_{amb} [b] specified Φ_e or ΔI_F specified	$\Delta\lambda_T$		x	nm/°C
	B. Monitor photodiode (where appropriate)					
9.6.6	Dark current	$\Phi_e = 0$, V_R specified	$I_{R(D)}$		x	μA
9.6.7	Monitor current	Φ_e or ΔI_F specified, V_R specified	$I_{R(M)}$	x	x	mA
9.6.8	Tracking error					
9.6.8.1	Tracking error [a]	Φ_e or ΔI_F, V_R specified, Temperature range: 25 °C to T_{case}, min. or T_{amb}, min.	E_{R1}		x	
9.6.8.2	Tracking error [b]	Φ_e or ΔI_F, and V_R specified Temperature range: 25 °C to T_{case}, max. or T_{amb}, max.	E_{R2}		x	
	C. Thermistor (where appropriate)					
9.6.9	Resistance	Thermistor current I_{tc} specified	R	x	x	Ω
9.6.10	Slope of resistance	Thermistor current I_{tc} specified Temperature range: T_{sub} [a], T_{sub} [b]	$\Delta R/R$	x	x	

Subclauses	Characteristics	Conditions at T_{sub} = 25 °C for laser modules with TEC, T_{amb} or T_{case} = 25 °C for laser module without TEC, unless otherwise specified	Symbols	Requirements		Units
				Min.	Max.	
	D. TEC element (where appropriate)					
9.6.11	TEC current	Φ_e or ΔI_F, specified Temperature range: T_{case} min. or T_{case} max.	I_{PE}		x	A
9.6.12	TEC voltage	Φ_e or ΔI_F, specified Temperature range: T_{case} min. or T_{case} max.	V_{PE}		x	V

[a] CW-operation.

[b] In modulation.

9.7 Supplementary information

- Median life under specified case temperature at specified output power.
- DC forward current of the laser diode corresponding to Φ_{eoo}.

NOTE Φ_{eoo} is the radiant power value of the laser chip on submount, representative of the performance and reliability of devices manufactured using the same technology and submitted to the same quality assurance procedures.

- Response time of the thermistor temperature with respect to the change of cooler current (where appropriate).
- Thermal resistance between laser diode junction and case (for the laser module without cooler).

9.8 Hazards

See IEC 60825.

10 Laser diode modules for fibre optic analogue transmission systems or subsystems

10.1 Type

The laser diode module consists of the following basic parts:

- laser diode;
- fibre pigtail (where appropriate);
- photodiode (where appropriate);
- thermal sensor (where appropriate);
- TEC element (where appropriate);
- isolator (where appropriate).

10.2 Semiconductor materials

The semiconductor materials of the laser diode modules for fibre optic analogue transmission systems or subsystems are

- laser diode: GaAs, GaAlAs, InGaAs, InGaAsP, InP etc.
- photodiode: Ge, Si, InGaAs, etc.

– thermal sensor:	where appropriate
– TEC element:	

10.3 Structure

Laser diode: distributed feedback (DFB), distributed Brag reflector (DBR), etc.

10.4 Details of outline and encapsulation

- IEC and/or national reference number of the outline drawing.
- Method of encapsulation: glass/metal/plastic/other.
- Terminal identification and indication of any electrical connection between a terminal and the case.
- Characteristics of the optical port: relative orientation to mechanical axis, relative position to mechanical axis, area, numerical aperture, etc.
- Information on the pigtail fibre: type of fibre, kind of protection, connector, length, etc.
- Information on the heatsinking of the package.

10.5 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 12 – Limiting values for laser diode modules for fibre optic analogue transmission systems or subsystems

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
	A. General conditions				
10.5.1	Storage temperature	T_{stg}	x	x	°C
10.5.2	Operating case temperature	T_{case}	x	x	°C
10.5.3	Operating submount temperature (where appropriate)	T_{sub}	x	x	°C
10.5.4	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		x	°C
10.5.5	Bend radius of pigtail (at specified distance from the case)	r	x		mm(cm)
10.5.6	Shock			x	m/s^2, s
10.5.7	Vibration			x	m/s^2, Hz
10.5.8	Tensile force along cable axis				
10.5.8.1	Untight structure – Tensile force on fibre – Tensile force on cable	 F F		 x x	 N N
10.5.8.2	Tight structure – Tensile force on cable	 F		 x	 N
	B. Laser diode [a]				
10.5.9	Reverse voltage	V_{R}		x	V
10.5.10	Continuous forward current	I_{F}		x	mA
10.5.11	Continuous radiant power	Φ_{e}		x	mW
10.5.12	ESD (HBM) [b]			x	V
	C. Photodiode (where appropriate)				
10.5.13	Reverse voltage	V_{R}		x	V
10.5.14	Forward current	I_{F}		x	mA
10.5.15	ESD (HBM) [b]			x	V

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
	D. Thermal sensor (where appropriate)				
10.5.16	Thermal sensor				
either 10.5.16.1	Dissipation	P_{tot}		x	W
or 10.5.16.2	Supply voltage	V_{supp}		x	V
	E. Thermo electric cooler (where appropriate)				
10.5.17	TEC current under cooling and heating	I_{PE}		x	A

[a] For laser module without TEC, the derating curve or derating factor shall be given for one of the following parameters of 10.5.10 to 10.5.13.
For laser module with TEC, T_{sub} = 25 °C.

[b] Both polarities.

10.6 Electrical and optical characteristics

Table 13 – Electrical and optical characteristics for laser diode modules for fibre optic analogue transmission systems or subsystems

Subclauses	Characteristics	Conditions at T_{sub} = 25 °C for laser module with TEC, T_{amb} or T_{case} = 25 °C for laser module without TEC, unless otherwise stated	Symbols	Requirements		Units
				Min.	Max.	
	A. Laser diode					
10.6.1	Forward voltage	Φ_{e} or I_{F} specified	V		x	V
10.6.2	Threshold current		$I_{\mathrm{(TH)}}$	x	x	mA
10.6.3	Forward current above threshold	Φ_{e} specified	ΔI_{F}[a]		x	mA
10.6.4	Differential efficiency	Φ_{e} or ΔI_{F} specified	η_{d}	x	x	mW/mA
10.6.5	Spectral characteristics					
10.6.5.1	Peak emission wavelength	Φ_{e} or ΔI_{F} specified, CW condition	λ_{p}	x	x	nm(µm)
10.6.5.2	Spectrum linewidth at –3 dB (where appropriate)	Φ_{e} or ΔI_{F} specified CW condition	$\Delta\lambda$		x	MHz
10.6.5.3	Sidemode suppression ratio	Φ_{e} or ΔI_{F} specified, CW condition	$SMSR$	x	x	dB
10.6.6	Modulation chirp	Φ_{e} or ΔI_{F} specified, modulation condition, and frequency range specified	α		x	nm/mA (nm/mW)
10.6.7	S_{21} parameter	Frequency range specified	S_{21}	x	x	
10.6.8	Relative intensity noise	Φ_{e} or ΔI_{F} specified, f_{n} and Δf_{n} specified, reflected optical power specified	RIN		x	dB/Hz
10.6.9	Composite second order distortion		CSO		x	dBc
10.6.10	Composite triple beat		CTB		x	dBc
10.6.11	Iintermodulation distortion					
10.6.11.1	Two-tone second order intermodulation distortion (where appropriate)		$IM2$		x	dB

Subclauses	Characteristics	Conditions at T_{sub} = 25 °C for laser module with TEC, T_{amb} or T_{case} = 25 °C for laser module without TEC, unless otherwise stated	Symbols	Requirements		Units
				Min.	Max.	
10.6.11.2	Two-tone third order intermodulation distortion (where appropriate)		$IM3$		x	dB
10.6.12	Reflectance	Φ_e (input) and λ_p specified	RL		x	dB
	B. Monitor photodiode (where appropriate)					
10.6.13	Dark current	$\Phi_e = 0$, V_R specified	$I_{R(D)}$		x	nA
10.6.14	Monitor current	Φ_e or ΔI_F specified, V_R specified	$I_{R(M)}$	x	x	mA
10.6.15	Tracking error					
10.6.15.1	Tracking error (25 → min.)	Φ_e or ΔI_F, V_R specified Temperature range: 25 °C at T_{case} min. or T_{amb} min.	E_{R1}		x	dB
10.6.15.2	Tracking error (25 → max.)	Φ_e or ΔI_F, et V_R specified Temperature range: 25 °C at T_{case} max. or T_{amb} max.	E_{R2}		x	dB
10.6.16	Total capacitance	$\Phi_e = 0$, frequency and V_R specified	C_{tot}		x	pF
	C. Thermal sensor (where appropriate)					
10.6.17	Resistance	Thermistor current I_{tc} specified	R	x	x	Ω
10.6.18	Slope of resistance	Thermistor current I_{tc} specified Temperature range: T_{sub} [b], T_{sub} [c]	$\Delta R/R$	x	x	
	D. TEC element (where appropriate)					
10.6.19	TEC current	Φ_e or ΔI_F, specified, Temperature range: T_{case} min. or T_{case} max.	I_{PE}		x	A
10.6.20	TEC voltage	Φ_e or ΔI_F, specified, Temperature range: T_{case} min. or T_{case} max.	V_{PE}		x	V
10.6.21	Temperature difference between T_{case} and T_{sub}	TEC current and voltage specified Laser operating condition	ΔT_{PE}		x	°C

[a] ΔI_F is defined as $\Delta I_F = I_F - I_{(TH)}$.

[b] CW-operation.

[c] In modulation.

10.7 Supplementary information

- Median life under specified case temperature at specified output power.
- DC forward current of the laser diode corresponding to Φ_{eoo}.

NOTE Φ_{eoo} is the radiant power value of the laser chip on submount, representative of the performance and reliability of devices manufactured using the same technology and submitted to the same quality assurance procedures.

- Response time of the thermistor temperature with respect to the change of cooler current (where appropriate).
- Thermal resistance between laser diode junction and case (for the laser module without cooler).

10.8 Hazards

See IEC 60825.

11 LED arrays for fibre optic systems or subsystems

11.1 Type

LED arrays with/without optical fibre pigtail for fibre optic systems or subsystems.

11.2 Semiconductor materials

GaAs, AlGaAs, InGaAs, InGaAsP, InP, etc.

11.3 Details of outline and encapsulation

- IEC and/or national reference number or outline drawing.
- Method of encapsulation: glass/metal/plastic/others.
- Terminal identification and indication of any electrical connection between a terminal and the case.
- Characteristics of the optical port: number of channels (LEDs), distance between channels, relative orientation to mechanical axis, relative position to mechanical axis, and numerical aperture.
- For devices with pigtail: information on a fibre pigtail, kind of protection, connector, and pigtail length.
- Information on the heat sinking of the package.

11.4 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 14 – Limiting values for LED arrays

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
11.4.1	Storage temperature	T_{stg}	x	x	°C
11.4.2	Operating temperature				
either 11.4.2.1	Operating ambient temperature	T_{amb}	x	x	°C
or 11.4.2.2	Operating case temperature	T_{case}	x	x	°C
11.4.3	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		x	°C
11.4.4	Reverse voltage	V_{R}		x	V
11.4.5	Continuous forward current with temperature derating curve or factor	I_{F}		x	mA
11.4.6	Repetitive peak forward current	I_{FRM}		x	mA
11.4.7	Power dissipation	P_{tot}		x	W (mW)
11.4.8	Virtual junction temperature [a]	$T_{\text{(vj)}}$		x	°C
11.4.9	Bend radius of pigtail (at specified distance from the case) [b]	r	x		mm (cm)
11.4.10	Shock			x	m/s^2, s
11.4.11	Vibration			x	m/s^2, s
11.4.12	Tensile force along cable axis [b]			x	m/s^2, Hz
11.4.12.1	Untight structure – Tensile force on fibre along its axis – Tensile force on fibre cladding along its axis	 F F		 x x	 N N
11.4.12.2	Tight structure – Tensile force on pigtail along its axis	 F		 x	 N

[a] For case rated devices only.

[b] For devices with pigtail only.

11.5 Electrical and optical characteristics

Table 15 – Electrical and optical characteristics for LED arrays

Subclauses	**Characteristics and conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated**	**Symbols**	**Requirements**		**Units**
			Min.	**Max.**	
11.5.1	Radiant power				
either 11.5.1.1	Radiant power at the optical port and at specified I_F	Φ_e	x	X[b]	mW
or 11.5.1.2	Forward current at specified radiant output power	I_F	X[b]	x	mA
11.5.2	Peak emission wavelength at specified I_F or Φ_e	λ_p	x	x	nm (µm)
11.5.3	Spectral radiation bandwidth at specified I_F or Φ_e	$\Delta\lambda$		x	nm
11.5.4 [a, b]	Half-intensity angle at specified I_F or Φ_e	$\theta_{1/2}$		x	°C
11.5.5 [a, b]	Misalignment angle between optical axis and mechanical axis at specified I_F or Φ_e	$\Delta\theta$		x	°C
11.5.6	Reverse current at specified I_F or Φ_e	V_F		x	V
11.5.7	Reverse current at specified V_R	I_R		x	V
11.5.8	Bandwidth				
either 11.5.8.1	Switching times at specified d.c. bias current, pulse width and duty cycle: – rise time – fall time – delay times [v]	t_r t_f $t_{d(on)}$ and $t_{d(off)}$		x x x x	ns ns ns ns
or 11.5.8.2	Cut-off frequency at specified I_F or Φ_e, noise frequency, bandwidth and modulation factor	f_c		x	MHz
11.5.9[v]	Total capacitance at specified V_R and frequency	C_{tot}	x	x	pF
11.5.10	Noise frequency				
either 11.5.10.1	Carrier to noise ratio at specified I_F or Φ_e, noise frequency, bandwidth and modulator factor	C/N		x	
or 11.5.10.2	Relative intensity noise at specified I_F or Φ_e, noise frequency and bandwidth	RIN		x	
11.5.11	Differential resistance at specified I_F or Φ_e	r_d		x	Ω
11.5.12[b]	Modulation current at 1 dB efficacy compression at specified Φ_e, R_L, λ_p, $\Delta\lambda$, and f	$I_{F(1dB)}$	x	x	mA
11.5.13[b]	Two-tone intermodulation distortion at specified Φ_e, R_L, λ_p, $\Delta\lambda$, and f	D_{12},D_{21}		x	dB
either 11.5.13.1[b]	Thermal resistance between junction and case	$R_{th(j-c)}$		x	Ω/K
or 11.5.13.2[b]	Thermal resistance between junction and ambient	$R_{th(j-a)}$		x	Ω/K
11.5.14[c]	Optical crosstalk at specified I_F	CR_O		x	dB
11.5.15[d]	Electrical crosstalk at specified I_F, i_f, clock frequency, and signal pattern	CR_E		x	dB

NOTE For reference only

The thermal crosstalk of channel "i", $CR_{th(i)}$, is defined by the quotient of ($\Phi_i' - \phi_i'$)/ Φ_i', where

- ϕ_i' is the radiant power emitted from the channel "i" when each channel (all channel including the i-th channel itself) is fed by specified $I_{F(DC)}$.
- Φ_i' is the radiant power emitted from the channel "i" when it is the only channel fed by specified $I_{F(DC)}$.

The thermal crosstalk of the device (array), CR_{th}, is the maximum of the overall crosstalks.

Subclauses	Characteristics and conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Symbols	Requirements		Units
			Min.	Max.	

[A] For devices without pigtail only.

[B] Where appropriate.

[C] The optical crosstalk of channel "i", $CR_{O(i)}$, is defined as the quotient of ϕ_i/Φ_i, where

- ϕ_i is the radiant power emitted from the channel "i" whilst each of all the other channels is fed by specified $I_{F(DC)}$,
- Φ_i is the radiant power emitted from the channel "i" when it is the only channel fed by $I_{F(DC)}$ specified.

The optical crosstalk of the device (array), CR_O, is the maximum of the overall crosstalks.

[D] The electrical crosstalk of channel "i", $CR_{E(i)}$, is defined as the quotient of ϕ_i/Φ_i, where

- ϕ_i is the average radiant power emitted from the channel "i" when each of all the other channels is fed by specified driving conditions, I_F, i_f, clock frequency and signal pattern (NRZ).
- Φ_i is the average radiant power emitted from the channel "i" when it is the only channel fed by specified driving conditions, I_F, i_f, clock frequency and signal pattern (NRZ).

The electrical crosstalk of the device (array), CR_E, is the maximum of the overall crosstalks.

11.6 Supplementary information

To be given only when necessary for the specification and the use of the device.

- Temperature derating curves referred to in the limiting values;
- Radiant output power versus temperature curve or coefficient;
- Radiant output power versus forward current curve;
- Change in peak emission wavelength versus temperature curve or coefficient;
- Radiation diagram;
- Thermal resistance (for ambient rated or case rated devices);
- Detailed outline drawings.

12 Optical modulators for digital fibre optic applications

12.1 Type

The optical modulator module consists of following basic parts;

- modulator (Mach-Zehnder type, electro-absorption type, etc.);
- input and output fibre pigtail (where appropriate);
- thermal sensor (where appropriate);
- TEC element (where appropriate);
- photodiode (where appropriate).

12.2 Materials

The materials of optical modulators for digital fibre optic applications are

- modulator: InP, GaAs, InGaAs, InAlAs, InGaAsP, $LiNbO_3$, etc;
- thermal sensor ;
- TEC element ;
- photodiode: Ge, Si, InGaAs, etc.

12.3 Structure

- Modulator: lumped type (Mach-Zehnder), travelling-wave type (Mach-Zehnder), Y-branch, MQW, etc.
- Optical isolator, photodiode, half-mirror, etc.

12.4 Details of outline and encapsulation

- IEC and/or national reference number of the outline drawing.
- Method of encapsulation: glass/metal/plastic/other.
- Terminal identification and indication of any electrical connection between a terminal and the case.
- Characteristics of the optical port: relative orientation to mechanical axis, relative position to mechanical axis, area, numerical aperture.
- Information on the pigtail fibre: type of fibre, kind of protection, length, connector type, angular orientation of the connector to the fibre polarization axis (where appropriate).
- Information on the heatsinking of the package.

12.5 Limiting values (absolute maximum ratings) over the operating temperature range, unless otherwise stated

Table 16 – Limiting values for optical modulators for digital fibre optic applications

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
	A. General conditions				
12.5.1	Storage temperature	T_{stg}	x	x	°C
12.5.2	Operating case temperature	T_{case}	x	x	°C
12.5.3	Operating submount temperature (where appropriate)	T_{sub}	x	x	°C
12.5.4	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		x	°C
12.5.5	Bend radius of pigtail (at specified distance from the case)	r	x		mm(cm)
12.5.6	Shock			x	m/s^2, s
12.5.7	Vibration			x	m/s^2, Hz
12.5.8	Acceleration (where appropriate)			x	m/s^2
12.5.9	Tensile force along cable axis:				
12.5.9.1	Untight structure				
	– Tensile force on fibre	F		x	N
	– Tensile force on cable	F		x	N
12.5.9.2	Tight structure				
	– Tensile force on cable	F		x	N
12.5.10	Change of temperature when operational (where appropriate)	$\Delta T/t$		x	°C/min.
	B. Modulator [a]				
12.5.11	Reverse voltage	V_R		x	V
12.5.12	Forward current	I_F		x	mA
12.5.13	Continuous input power	$\Phi_{e(in,cw)}$		x	mW
	C. Thermal sensor (where appropriate)				
12.5.14	Thermal sensor				
either 12.5.14.1	Dissipation power	P_{tot}		x	W
or 12.5.14.2	Supply voltage	V_{supp}		x	V

Subclauses	Characteristics	Symbols	Requirements		Units
			Min.	Max.	
	D. Thermo-electric cooler (where appropriate)				
12.5.15	TEC current under cooling and heating	I_p		x	A
	E. Photodiode (where appropriate)				
12.5.16	Reverse voltage	V_R		x	V
12.5.17	Forward current	I_F		x	mA
NOTE Relative humidity and air pressure should be specified for all devices in non-hermetically sealed packages.					
[a] For modulator module without TEC, the derating curve or derating factor shall be given for one of the parameters of 12.5.9 to 12.5.11. For modulator module with TEC, T_{sub} = 25 °C.					

12.6 Electrical and optical characteristics

Table 17 – Electrical and optical characteristics for optical modulators for digital fibre optic applications

Subclauses	Characteristics	Conditions at T_{sub} = 25 °C for modulators with TEC, T_{amb} or T_{case} = 25 °C for modulators without TEC, unless otherwise stated	Symbols	Requirements		Units
				Min.	Max.	
	A. Modulator					
12.6.1	Operating voltage	Extinction ratio specified, d.c. bias specified	V_π	x	x	V
12.6.2	Operating wavelength	Polarization, wavelength and input power specified	λ_{op}	x	x	nm (µm)
12.6.3	Insertion loss	Polarization, wavelength and input power specified	L_{in}		x	dB
12.6.4	Return loss	Polariztion, wavelength and d.c. bias specified	R_L	x	x	dB
12.6.5	Extinction ratio	Polarization, wavelength and input power specified, d.c. bias specified	$E \times R$	x	x	dB
12.6.6	Frequency response	Polarization, wavelength and input power specified, d.c. bias specified	f_c		x	MHz (GHz)
12.6.7	Frequency response flatness	Polarization, wavelength and input power specified, d.c. bias specified	$\Delta R_D/R_D$		x	MHz/mV
12.6.8	Wavelength chirp	Polarization, wavelength and input power specified, d.c. bias specified	α		x	MHz/mV
	B. Thermistor (where appropriate)					
12.6.9	Resistance	Thermistor current I_{tc} specified	R	x	x	Ω
12.6.10	Slope of resistance	Thermistor current I_{tc} specified Temperature range: T_{sub} [a],T_{sub} [b]	$\Delta R/R$	x	x	
	C. Thermo-electric cooler element (where appropriate)					

Subclauses	Characteristics	Conditions at T_{sub} = 25 °C for modulators with TEC, T_{amb} or T_{case} = 25 °C for modulators without TEC, unless otherwise stated	Symbols	Requirements		Units
				Min.	Max.	
12.6.11	TEC current	V_π specified Temperature range: T_{case} min. or T_{case} max.	I_{PE}		x	A
12.6.12	TEC voltage	V_π specified, Temperature range: T_{case} min. or T_{case} max.	V_{PE}		x	V
12.6.13	Temperature difference between T_{case} and T_{sub}	TEC current, voltage and modulator operating condition specified	ΔT_{PE}		x	°C
	D. Monitor photodiode (where appropriate)					
12.6.14	Dark current	$\Phi_e = 0$, V_R specified	$I_{R(D)}$		x	nA
12.6.15	Monitor current	Φ_e specified V_R specified	$I_{R(M)}$	x	x	mA

[a] CW-operation.

[b] In modulation.

12.7 Supplementary information

- Extinction ratio (or output power) as a function of reverse voltage.
- Response time of the thermal sensor temperature with respect to the change of cooler current (where appropriate).
- Bias stability (where appropriate).
- Bias temperature coefficient, in either V/°C or %/°C (where appropriate).

12.8 Hazards

See IEC 60825.

Bibliography

IEC 60050-731, *International Electrotechnical Vocabulary – Chapter 731: Optical fibre communication*

IEC 60050-845, *International Electrotechnical Vocabulary – Chapter 845: Lighting*

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